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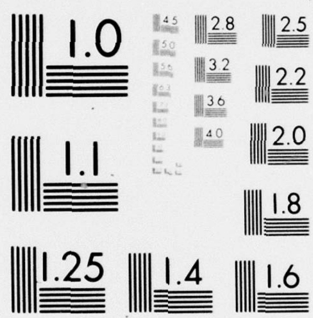
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An Assembly-Language Digital Division Computer Program for Use in Proton-Recoil Spectroscopy

September 1977

U.S. Army Materiel Development
and Readiness Command
HARRY DIAMOND LABORATORIES
Adelphi, Maryland 20783

TM-77-20—An Assembly-Language Digital Division Computer Program for Use in Proton-Recoil Spectroscopy by Craig R. Heimbach

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER (14) HDL-TM-77-20	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER (9)
4. TITLE (and Subtitle) (6) An Assembly-Language Digital Division Computer Program for Use in Proton-Recoil Spectroscopy.	5. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Craig R. Heimbach	8. CONTRACT OR GRANT NUMBER(s) Pron: A1-7R000402A1A9
9. PERFORMING ORGANIZATION NAME AND ADDRESS Harry Diamond Laboratories 2800 Powder Mill Road Adelphi, MD 20783	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program: 6.21.18.A
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Materiel Development and Readiness Command Alexandria, VA 22333	12. REPORT DATE (11) September 1977
	13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (12) 12p.	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

HDL Project No.: X75721
DRCMS Code: 6121188750011

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Proton recoil
Computer program
Pulse-height division

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computer program has been modified to circumvent the need for an analog divider for a neutron-energy spectrometer in use at the Harry Diamond Laboratories. The spectrometer is a proton-recoil system, and some division process is necessary to discriminate against gamma sensitivity of the gas proton-recoil detectors.

The program is written in basic machine language for the minicomputer that controls spectrometer operation and collects and →

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analyzes data. Coincident dual-parameter data (energies of recoiling protons and pulse rise times) are acquired by the program. The rise-time pulse-height distribution is divided by the energy distribution before storage in the computer memory. This normalization facilitates subtraction of the unwanted gamma sensitivity of the proton-recoil detectors, particularly at low neutron energies.

The elimination of the analog divider improves performance and simplifies the operation of the spectrometer.

CONTENTS

FIGURES

1. INTRODUCTION

Harry Diamond Laboratories (HDL) is presently developing a capability for fast-neutron spectrometry. One method being pursued is the proton-recoil technique.[1,2,3] With this method, neutrons from a nuclear reactor penetrate a detector containing hydrogen or methane gas and collide with the protons. The protons recoil and create in the gas ion pairs that are collected by an applied electric field. The voltage pulses resulting from the collected ions are proportional to the energy of the protons. Pulse-height analysis of the voltage pulses allows the energy spectrum of the protons to be determined. The proton spectrum is then analyzed to provide the energy spectrum of the high-energy neutrons.

Any cause of ionization in the detector gas other than the protons is a source of noise. In particular, gamma rays that accompany the high-energy neutrons also ionize the gas. Voltage pulses that have gamma rays as their origin must be separated from those which are due to the neutrons.

2. METHOD OF GAMMA-RAY DISCRIMINATION

Usually, this separation of pulses is performed by pulse-shape discrimination. Because the protons have a greater specific ionization than Compton electrons that result from gamma interactions, they have shorter path lengths in the gas. Hence, their voltage pulses have shorter rise times than those due to the gamma rays.

Figure 1 illustrates the pulse-separation technique. Figure 1(a) shows the differences in pulse-height distributions from neutrons and gamma interactions. In figure 1(b), the separation is increased for the smaller pulse heights by use of specific ionization rather than rise time to distinguish between the neutron- and gamma-ray-induced pulses. The specific ionization is obtained by dividing the rise time of each voltage pulse by its magnitude. The resulting dual-parameter distribution is pictured in figure 2.

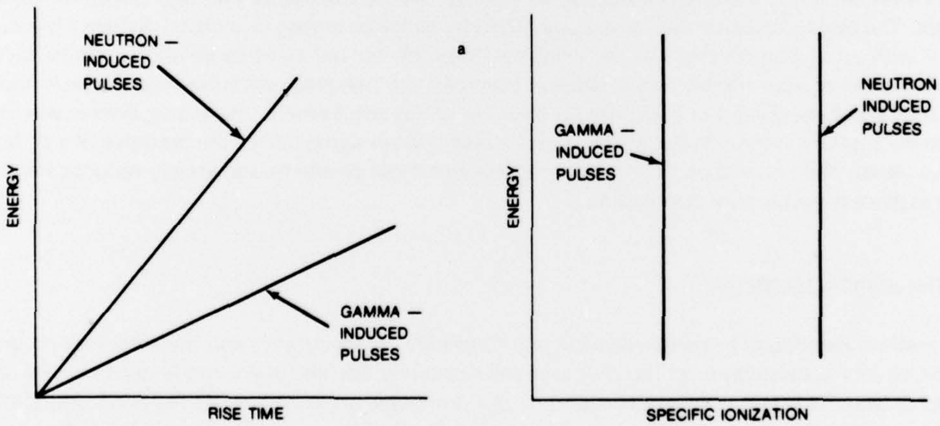

Figure 1. Distributions of neutron and gamma-ray pulses. Energy versus rise time (a) and energy versus specific ionization (b).

[1] E. F. Bennett and T. J. Yule, *Techniques and Analyses of Fast-Reactor Neutron Spectroscopy with Proton-Recoil Proportional Counters*, Argonne National Laboratory, ANL-7763 (1971).

[2] E. F. Bennett, Nuclear Science Engineering, *27*(1967), 16-27.

[3] Fast Neutron Physics, *VI*, Ch IIA, Interscience (1966).

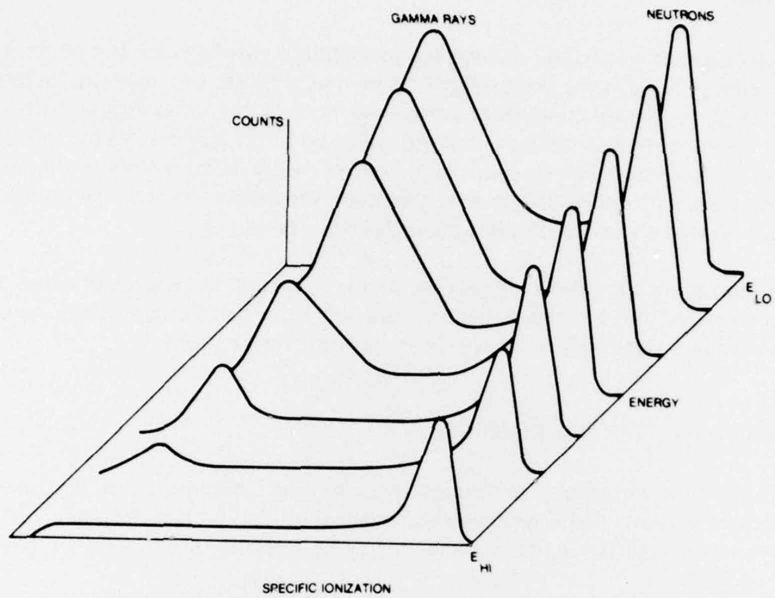

Figure 2. Dual-parameter data distribution.

3. DIFFICULTIES WITH METHOD

A key element of the gamma-ray separation technique is the division of rise-time pulses by voltage pulse height. The desired division can be accomplished by either an analog or a digital divider. However, experience with an analog divider was the principal emphasis for our need to develop a digital divide technique. In order to perform the analog division correctly, the rise-time and pulse-height signals had to enter the analog voltage divider in coincidence. Because of this requirement, the analog divider was very sensitive to fluctuations in time. It was also sensitive to variation in signal size or the presence of a dc level *in the input signal. The elimination of the divider eliminates these problems and greatly reduces the time* necessary to place the system into operation.

4. METHOD OF SOLUTION

The method developed to do this division was to modify the electronics and the computer program which control data acquisition from the proton-recoil detectors. The electronic modification is relatively simple and is described first. The modification of the computer program and background information necessary to operate the program and to interpret the results are discussed in the remainder of the report.

5. ELECTRONIC MODIFICATIONS

Originally, the electronics that couple the proton proportional counters (the detectors for the neutron spectrometer) through the ADC's (analog-to-digital converters) to the minicomputer were arranged as shown in figure 3. The signals from the proton-recoil counters were amplified to give a total amplitude

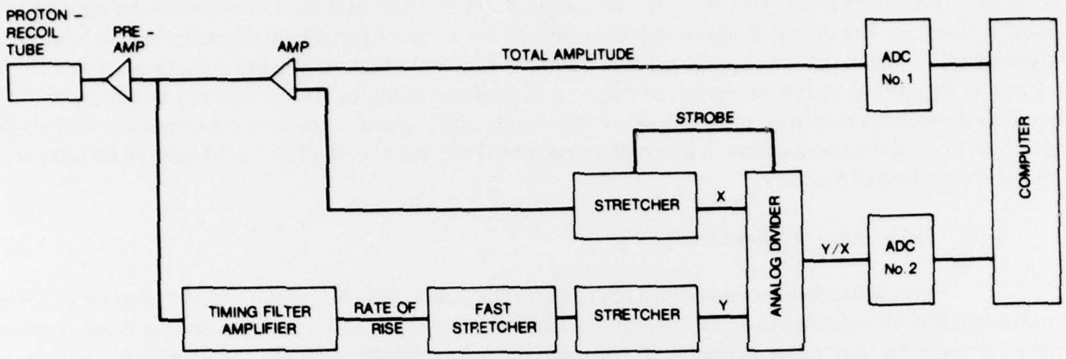

Figure 3. Electronics with analog voltage division.

pulse in one ADC. Such pulses are proportional to the energies of the recoiling protons. Simultaneous with this energy measurement, the timing-filter amplifier differentiates and amplifies the signals to give the rate of rise. These signals (energy and rate of rise) are fed in coincidence into the Y/X analog-voltage divider to produce the input to the second ADC, which forms the specific ionization axis of the dual-parameter array.

Since the ADC's and memory units are under control of a minicomputer, it is possible to have the alternative arrangement shown in figure 4. The total amplitude (energy) signal is the same as before, but since the Y/X division is now done digitally within the minicomputer, the second ADC accepts rate-of-rise information directly.

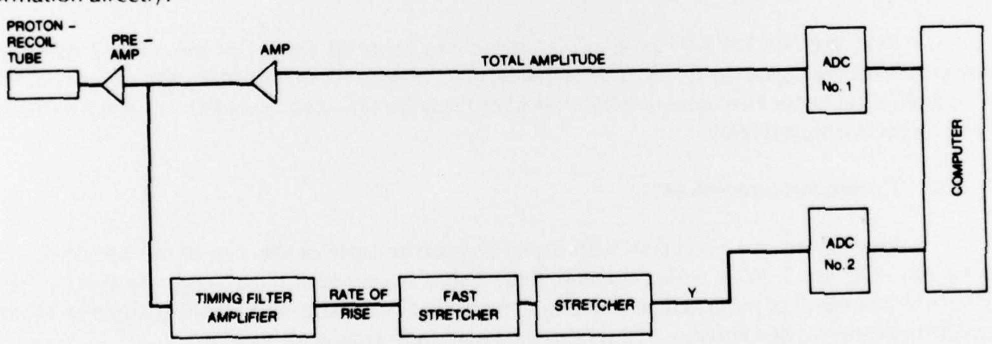

Figure 4. Electronics with digital voltage division.

6. PROGRAM MODIFICATIONS

6.1 *Description of Program*

The digital divide program is listed in appendix A. It is written in assembly language[4] for the ND812 computer and is in the form of an overlay for the ND-1075-01, which is the dual-parameter data-acquisition program.[5]

[4] Nuclear Data Incorporated, Software Instruction Manual, BASC-12 General Assembler, Palatine, IL (1962).

[5] Nuclear Data Incorporated, Software Instruction Manual, ND4420 Single/Dual Parameter Monitor, Palatine, IL (1972).

The ND-1075-01 has a special subroutine which handles data coming from the ADC's. Normally, this subroutine polls the ADC's to collect X and Y input and then increments the appropriate point in memory. The digital divide modification leaves the X input unchanged, but modifies the Y input by dividing it by X. Then the appropriate point in memory is incremented. All the other routines of ND-1075-01 are unaffected, with the exception of the auto-experiment routines. These routines are changed only because the overlay had to be put somewhere in memory and the auto-experiment routines are rarely used for proton-recoil data acquisition. If one had to use these routines, the overlay would have to be moved to an unused portion of memory.

6.2 *Explanation of Subroutines*

The digital divide overlay consists of four subroutines: RSSAV, RSRES, NEW1, and NEW2. The subroutine RSSAV modifies the ADC handling routine to save the R and S registers so that these registers may be used by the other portions of the ND-1075-01. RSRES restores the R and S registers to whatever their original contents were before the ADC interrupt occurred. This is necessary because the R and S registers have meaning to portions of the 1075 program external to the ADC routines. Location FIRST also has to be saved and restored because the location of the patches eliminates the instruction that normally does this.

The routine NEW1 stores the results of the X-ADC for future reference. The routine NEW2 takes the results of the Y-ADC, multiplies by a scale factor FMP, divides by the X-ADC results, and then returns control to the ND-1075-01 program with the results in the K register. The ND-1075-01 uses the results in the K register as the Y input and increments the appropriate location in memory.

6.3 *Use of Program*

First, the ND-1075-01 program is loaded into fields 00 and 01 of the ND812 computer. A binary version of the digital divide program is overlaid on top of this in field 00 by the paper-tape loader. The multiplication factor FMP (location 7507, field 00) may be varied to move the Y/X result to the left or right on an oscilloscope display.

6.4 *Constraints on Method*

Precautions must be taken with digital division because of the size of the rate-of-rise pulses coming into ADC no. 2. With analog division, these pulses consisted of pulse height divided by rise time and were independent of pulse height. Therefore, the gain of the timing filter amplifier could be set to give adequate resolution at one energy and it was automatically adequate at all energies.

In the digital division arrangement, the pulses coming into ADC no. 2 are proportional to energy. One may set the timing filter amplifier to give adequate resolution in the middle of the energy range, but there are still problems at the extreme low and high ends of the energy range.

First, consider the low end of the energy range. The input to ADC no. 2 consists of small voltage pulses, which are digitized to only a few significant figures. This causes a loss of accuracy in the rise time, making the separation of gamma rays more difficult. Fortunately, sufficient accuracy may be achieved in the digital technique by increasing the resolution of ADC no. 2 from 256 divisions full scale, which was adequate with the analog division arrangement, to 4096.

Next, consider the high end of the energy range. The input pulses to ADC no. 2 grow larger with energy and may exceed the maximum signal capacity of the ADC. If this occurs, data will be lost. This data loss may be avoided by keeping the gain of the timing filter amplifier sufficiently low.

The operator must remember to set the resolution of ADC no. 2 to 4096. Since the overlay automatically interacts with the ND-1075-01, no further action on the part of the operator is necessary.

7. SUMMARY

An assembly-language computer program has been written which allows the electronic analog divider to be eliminated from the HDL proton-recoil spectroscopy system. This has the advantage of simplifying the electronics and greatly reducing the time necessary to set up the system. In order to use the program, the resolution of ADC no. 2 (the rise-time ADC) has to be increased to 4096 divisions and care must be taken to see that the rise-time signal does not grow beyond the capacity of ADC no. 2 before the energy signal grows beyond the capacity of its ADC.

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2. E. F. Bennett, Nuclear Science Engineering, *27*(1967), 16-27.

3. Fast Neutron Physics, *VI*, Ch IIA, Interscience (1966).

4. Nuclear Data Incorporated, Software Instruction Manual, BASC-12 General Assembler, Palatine, IL (1962).

5. Nuclear Data, Incorporated, Software Instruction Manual, ND4420 Single/Dual Parameter Monitor, Palatine, IL (1972).

APPENDIX A.—DIGITAL DIVIDE PROGRAM

This digital divide program is written in assembly language[1] for the ND812 computer. It is in the form of an overlay for the ND-1075-01, which is the dual-parameter data-acquisition program.[2]

```
O
V
U


SE 5353
EXJK     = 1374
FMP      = 7407
NEW1     = 7400
NEW2     = 7410
NEWP     = 7400
RSRES    = 7440
RSSAV    = 7425
RSTR     = 7436
SSTR     = 7437
X        = 7406
ER 0000
A
A<A< A<B<\,< = < =))<=
                        ( },(<)<(G<

              EXJK=1374
              NEWP=7400        /NEWP LOCATES THE OVERLAY
                                POSITION
/ THE FOLLOWING TWJMP'S ARE PATCHES INTO THE 1075 WHICH
/  DIRECT IT TO THE DIGITAL DIVIDE ROUTINES
/
                       *0111

0111   0600            TWJMP
0112   7425            RSSAV

                       *0117
0117   0600            TWJMP
0120   7440            RSRES

                       *0136

0136   0600            TWJMP
0137   7400            NEW1
```

[1] Nuclear Data Incorporated, Software Instruction Manual, BASC-12 General Assembler, Palatine, IL (1962).

[2] Nuclear Data Incorporated, Software Instruction Manual, ND4420 Single/Dual Parameter Monitor, Palatine, IL (1972).

```
                    *0210

0210  0600          TWJMP
0211  7410          NEW2

                    *NEWP

/ UPON ENTERING NEW1, J CONTAINS THE VALUE OF THE X ADC.
/ THE EXJK, TWSTJ DO WHAT USED TO BE DONE BY THE 1075
/  WHERE THE TWJMP NEW1 IS NOW LOCATED
/
7400  5406  NEW1,   STJ X
7401  1374          EXJK
7402  0540          TWSTJ
7403  0175          0175
7404  0600          TWJMP
7405  0140          0140     /RETURN TO THE 1075

7406  0000  X,      0
7407  0400  FMP,    0400     /NORMALIZATION FACTOR

/ NEW2 TAKES THE Y-ADC VALUE, MULTIPLIES BY THE SCALE FACTOR
/  FMP, DIVIDES BY THE X-ADC VALUE, AND STORS THE RESULT INTO
/  THE 1075 SO THAT THE APPROPRIATE DATA LOCATION MAY BE
/  INCREMENTED AND DISPLAYED
/
7410  1374  NEW2,   EXJK     /K=Y AFTER
7411  0540          TWSTJ    / SAVE J
7412  0175          0175
7413  5104          LDJ FMP
7414  1000          MPY      /NORMALIZE Y
7415  5107          LDJ X
7416  1303          EXJRKS
7417  1001          DIV      /Y/X
7420  1374          EXJK     /PUT IN K
7421  0500          TWLDJ    / RESTORE J
7422  0175          0175
7423  0600          TWJMP
7424  0212          0212     /RETURN TO 1075

/ RSSAV SAVES THE CONTENTS OF THE R AND S REGISTERS
/  SO THAT R AND S MAY BE USED IN THE DIVIDE INSTRUCTION
/
/ FIRST MUST BE SAVED BECAUSE THE TWJMP RSSAV IS IN THE
/  LOCATION WHERE FIRST IS USUALLY SAVED
/
```

```
7425  5000  RSSAV,  LDJ FIRST
7426  0540          TWSTJ
7427  0173          0173      /STORAGE LOCATION FOR FIRST IN ADC
7430  1302          LJKFRS     INTERRUPT
7431  5405          STJ RSTR
7432  0550          TWSTK
7433  7437          SSTR
7434  0600          TWJMP
7435  0113          0113      /RETURN TO 1075

7436  0000  RSTR,   0         /STORAGE LOCATION FOR R
7437  0000  SSTR,   0         /STORAGE LOCATION FOR S

/ RESTORE R AND S BEFORE LEAVING ADC INTERRUPT ROUTINE
/
7440  5102  RSRES,  LDJ RSTR
7441  0510          TWLDK
7442  7437          SSTR
7443  1301          LRSFJK
7444  1410          CLR FLAG
7445  1450          CLR O
7446  0600          TWJMP
7447  0121          0121


SE 5353
EXJK     = 1374
FMP      = 7407
NEW1     = 7400
NEW2     = 7410
NEWP     = 7400
RSRES    = 7440
RSSAV    = 7425
RSTR     = 7436
SSTR     = 7437
X        = 7406
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